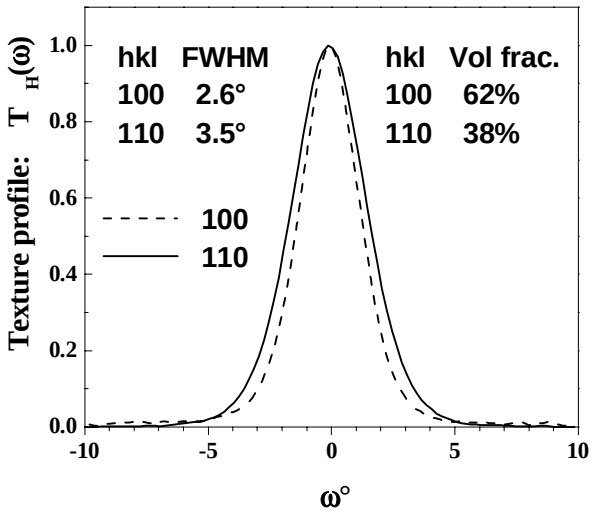
Texture Measurements in Thin Film and Bulk Materials

Mark D. Vaudin

Many thin film and bulk materials used in electronic applications have a preferred crystallographic orientation or texture. Properties of materials can be strongly affected by texture. To optimize the development and application of textured materials, it is desirable to quantify the effects of texture on properties, which requires accurate characterization tools. NIST has developed quantitative texture measurement techniques that employ equipment commonly available in most industrial and academic settings.

The properties and performance of electronic devices can be strongly dependent upon the texture of the various material layers. For example, the remanent polarization in $PbZr_xTi_{1-x}O_3$ (PZT) films used in nonvolatile RAM is orientation-dependent, so the ability to switch domains during a writing operation is strongly influenced by the PZT texture. Quantifying texture effects on properties requires accurate measurement of the texture. This project addresses issues relevant to texture measurement with particular emphasis on electronic materials.

Classical texture measurement methods require specialized equipment that is not routinely available in most laboratories. We have developed an accurate technique for measuring fiber (i.e., axisymetric) texture that uses a conventional θ-2θ x-ray diffractometer. In our approach, θ-2θ and ω scans are collected from the specimen and corrected for defocusing and absorption effects using custom software developed for this project. Accurate texture profiles are calculated from the corrected data. Volume fractions of various textured populations can be determined for films with multimodal texture from the texture profiles and the *hkl* Bragg intensities relative to intensities from untextured films of the same phase. For example, the figure below shows texture profiles for a $Ba_xSr_{1-x}TiO_3$ (BST) film with mixed (100) and (110) texture. The volume fractions of (100)-oriented (60% ±5%) and (110)-oriented (40% ±5%) material calculated using our more comprehensive method are significantly different from the values of 75% ±5% (100) and 25% ±5% (110) based only on integrated peak intensity measurements.



Our TexturePlus software package is available on the web at http://www.ceramics.nist.gov/webbook/TexturePlus/texture.htm. Tools for simple analysis of θ-2θ patterns and integration of corrected texture profiles for volume fraction determinations are included. IBM and Ramtron Corp. have used our technique to measure texture in BST DRAM films and PZT nonvolatile RAM films respectively.

We organized and held a workshop on Texture in Electronic Applications at the NIST Gaithersburg site on October 10 and 11, 2000. The primary goal of the workshop was to provide a forum for the discussion of critical issues relevant to texture and texture measurement. The major topics were:

- Production and control of texture in a variety of different device materials
- Different methods of texture measurement and conditions for which each method is applicable
- Texture analysis procedures
- Effects of texture on properties and performance
- Effects of texture on processing of subsequent layers deposited upon a textured template

A deliberate effort was made to engage participants involved in a broad array of materials, measurement techniques and application areas in order to provide an opportunity for meaningful interchange and collective insight into the measurement needs of the texture community. The nearly 40 attendees were evenly divided between industry, universities and national labs. During roundtable discussions, it became clear that there is a strong need for texture standards. A prerequisite for standards development is interlaboratory comparisons of results obtained on the same specimens with different techniques, and also on the same specimens using the same technique but different equipment. NIST agreed to take the lead in organizing such an activity, and will continue to design and validate texture measurement procedures for the specific needs of the texture community. A report on the Workshop will be published in the NIST Journal of Research.

Contributors and Collaborators

Thomas M. Shaw (IBM, Thomas J. Watson Research Center)
Glen R. Fox (Ramtron Corporation)